Carnegie Mellon
Software Engineering Institute

Viewing Technologies for Computer-Aided Design Models

Michelle Potts Steves
Simon Frechette
Manufacturing Systems Integration Division
Manufacturing Engineering Laboratory
National Institute of Standards and Technology

Edited by:
John T. Foreman
William B. Anderson
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September 2003

**Technology Insertion Demonstration
and Evaluation Program (TIDE)**

Technical Note
CMU/SEI-2003-TN-022

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Preface

This report was funded by the Technology Insertion Demonstration and Evaluation (TIDE) Program. The TIDE Program was established to accelerate the diffusion and adoption of advanced software technologies to help U.S. manufacturers. The mission of the program is to identify barriers to adoption of software technology within the community of small manufacturing enterprises and to help that community overcome those barriers.

One such barrier to adoption of tools supporting distributed, computer aided design (CAD)-model review is a lack of understanding of the characteristics of these tools, the formats they support, and other important considerations for a requirements review and product evaluation. CAD-model review tools are attractive because they offer the possibility of expanding engineering data review and collaboration to the extended enterprise.

However, finding the right tool is not usually a simple matter. There is a broad range of CAD-model viewing tools on the market today with widely varying capabilities. Choosing an appropriate tool for a given situation requires an understanding of the functionalities these tools provide and deployment-specific requirements. This report addresses the identified barrier to adoption of distributed, CAD-model review tools by documenting tool characteristics with brief explanations of the functionality they provide, the various types of CAD-model formats, as well as issues to consider when performing a needs analysis and comparative product evaluation[1] with the intent of acquiring a CAD-model viewing solution.

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[1] Any commercial product identified in this document is for the purpose of describing a software environment. This identification does not imply *any* recommendation or endorsement by the National Institute of Science and Technology, the Software Engineering Institute, Carnegie Mellon University or the Technology Insertion Demonstration and Evaluation Program.

Abstract

This report provides information about technologies for viewing computer-aided design (CAD) models. CAD model viewers are tools that allow engineers and other users to view CAD models from distributed locations, often using lightweight viewing applications or standard Web browsers. The report describes factors to consider when choosing a viewing technology, as well as popular CAD model file formats that viewing technologies can import. Also provided is a sampling of commercial off-the-shelf (COTS) products currently available for viewing CAD models; descriptive information for each product, such as basic product functionality, purchase price, computer platform support, file format support; and a related World Wide Web Universal Resource Locator.

1 Introduction

Tools for viewing computer-aided design (CAD) models hold great potential for small manufacturers. These tools allow engineers and others involved in product development and review to view 3D models from distributed locations, often using lightweight viewing applications or standard Web browsers. Visualization solutions are also useful when multiple CAD systems are used throughout an organization, because many viewers support multiple CAD formats. Viewers solve the problem of such heterogeneity, allowing every authorized member in the organization to see designs from a variety of formats without running full-function CAD systems. Some viewers can enable a design review meeting over the Internet by allowing project members to view and analyze a model concurrently while shifting control between members. Common functionality other than visualization over the network includes mark-up, geometric measurement, extraction of inertial properties, and generation of cut views.[2]

Visualization solutions are distinct from manipulation solutions. Manipulation solutions are typically native CAD systems that support changing the CAD model, as opposed to only reviewing the model or a representation of the model. Visualization solutions are typically much less costly, and faster and simpler to use than native CAD systems for the purpose of supporting model review and analysis.

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2 Background

There is a plethora of viewing technologies for CAD on the market today. These tools provide a broad range of functionality from simple viewing of printer-formatted representations of CAD models to advanced operations such as data management systems queries, simulation, animation, fly-through, collision detection, and assembly analysis. Viewer tools often allow users to rotate, zoom, section-view, measure, and mark up three dimensional (3D) models or assemblies. CAD system vendors generally offer viewers that are restricted to the formats of the CAD models they offer. These viewers are useful if there is only one CAD system being used in the extended enterprise. Independent viewers cover a variety of file formats[3] for two dimensional (2D) and 3D CAD and other documentation. Some independent viewers support more than two hundred file formats.

Viewer tools typically provide good support for project review and verification activities, but may not support active, co-design activities adequately. Collaborative design activities, as opposed to product review, often require capabilities such as interaction with the CAD software to change the model (rather than merely view it), version control with associated design rationale at different levels of abstraction, and coordination provided by a workflow management system using a product realization process manager. These capabilities are more extensive than most viewing technologies provide.

2.1 Viewing Technology Capabilities

This section provides a brief overview of the various capabilities that viewing technology may provide:

- access control – mechanisms to restrict or grant access to specified model elements or files

- animation – a simulation of movement created by displaying a series of pictures or frames

- assembly analysis – computer-aided engineering (CAE) functions used to provide assessment of the behavior of the design

- collision detection – CAE function used to detect interference issues

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[3] *File format* refers to a format for encoding information in a file. Different file formats distinguish one type of file from another. The file format specifies first whether the file is a binary or ASCII file, and second, how the information contained in the file is organized.

- conversion or translation – exports to a different file format. (Some data loss may occur depending on the type of conversion.)

- cut view or cross-section – produces a cross-section view of an object

- data management system queries - provides access and view of product data, typically in context with the visual model

- document management – mechanisms to organize various documents and files related to a product or other entity

- edit – typically provides the ability to change appearance features of a drawing, such as line color

- extraction of inertial properties – extracts inertial properties, such as mass properties

- fly-through – provides real-time changes to the viewed area by creating the impression of moving through the object space

- geometric measurement – measurement capabilities between geometric entities in the model

- mark-up – drawing and annotation feature (sometimes called "redlining," however redlining is being subsumed by mark-up capabilities)

- mirror – produces a mirror image of the object

- model comparison – compares revisions between two models and highlights the differences

- pan – changes the viewed area while maintaining a fixed perspective for the viewer

- plot – produces an image by drawing lines, either on a display screen or on paper

- print – creates text or illustrations on paper via a printer

- publish – exports formats of views in Web and other publishing formats

- rotate – changes the perspective of the view of an object

- scale – changes the size of an object while maintaining its shape

- section-view – creates sections of an assembly to view separately

- simulation – the process of imitating a real phenomenon with a set of mathematical formulas

- viewing – presentation of a computer-generated, graphical image

- zoom – enlarges the view of an object, enabling the user to see more detail

3 Choosing a Viewing Technology

3.1 Requirements and Needs Analysis

When choosing a viewing/visualization technology, a company must first determine its needs, and then the ability of each candidate application to meet those needs. The most important issues are what CAD formats need to be supported and who will use the technology. Relative to this latter issue, engineers need specific capabilities that are often found in more advanced features of visualization tools, whereas others may need an easy-to-use, viewing tool. Requirements-gathering efforts should also include creating a list of database and process applications that will need to be accessed from the viewing/visualization technology. Questions that should be addressed during a requirements gathering effort include

- What CAD formats must be viewed?

- Who needs to view the CAD models?

- What capabilities are required? (See list in previous section.)

- What types of computers will the software run on?

- What is the file size of a typical CAD model to be viewed?

- Does sufficient communication capacity to move the CAD data exist?

- As the viewing technology becomes more valuable to the organization, can it be (easily) integrated with other IT systems? Do the relevant technologies have open Application Program Interfaces (APIs)?

- What are the viewing management requirements, such as confidentiality and access control during design review?

- Are customizable interfaces required or anticipated?

3.2 Integration Issues

As mentioned in the previous section, when choosing a viewing technology, it is important to realize that the functionality the viewing technology affords may become embedded in and change various business processes. Therefore, attention should be given to these candidate business processes and viewing technologies with future integration issues in mind. For instance, do all the existing and candidate technologies involved have open APIs? Changing business processes call for the review of the ability of legacy and candidate systems to meet new needs.

3.3 Future

In the current state, many existing and evolving technologies meet niche market needs. This state is unlikely to change in the near future, as CAD system vendors strive to support their proprietary models, and generic, computer-graphics technologies are evolving at a rapid pace. In this changing marketplace, users of these technologies should identify their current and future needs and strive to find solutions that meet those needs, with the expectation of periodically repeating this needs analysis.

4 Model Formats

CAD models are stored in many different formats. The main reason there are different model formats is that different CAD systems have their own, often proprietary, model formats. These formats are typically rich in information beyond the model's geometry data, including such information as design intent, design history, and constraint information. Examples of these so-called "native" CAD formats include CATIA, Pro-Engineer, and I-DEAS.

Additionally, some formats have evolved, been developed, or been co-opted as exchange formats between various CAD systems and other applications. These formats do not contain all the information that native formats contain, however, they have the desirable property of conveying a representation of the CAD data to other applications. Examples include

- Three-dimensional solid shape data exchange with a kernel-based data format, which is often supported and used between CAD products that utilize the same modeling kernel

- Neutral (non-proprietary) specifications for shape and product data exchange such as IGES[4] and STEP[5]

- Computer graphics technology that is used to view three-dimensional images, including 3-D representations of CAD data, such as 3D Studio

In response to the urgent need of solving parametric CAD data interchange problems, many services and translators have sprung up providing exchange of product data including feature, history and constraint information, with proprietary technologies. Although translation solutions are an important option for exchanging product data between CAD and other engineering and business systems, they are only pertinent to this discussion of viewing technologies when a viewer is not available for a particular CAD format. Fortunately, this is not the typical case, as viewing technology vendors have embraced an array of model formats. And, as noted above, some viewing solutions support more than 200 formats.[6]

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[4] IGES is the acronym for Initial Graphics Exchange Specification. See the section on Exchange Specifications for further information.

[5] STEP is the acronym for STandard for the Exchange of Product model data. See the section on Exchange Specifications for further information.

[6] Although some products claim to support a large number of formats, often these supported formats are not CAD model formats, but are other document formats. These include CompuServe Graphics Exchange Format (GIF), Encapsulated PostScript (EPS), MacPaint (MACPNT), Microsoft Windows 3.1 Icon (ICO), and Microsoft Windows Bitmap (BMP). Care should be exercised to identify requirements and application capabilities.

Additionally, most CAD system vendors provide a free viewing solution for their model formats.

4.1 Native CAD Formats

This section lists popular native CAD systems. The company name is given parenthetically after the product name. Some of these systems support additional capabilities, such Computer-Aided Manufacturing (CAM) and CAE. These capabilities are identified in the "System type" item for each product; however, it should be noted that some systems have additional modules that can perform these functions and that system packaging is subject to change. Additionally, it is often helpful to know what type of modeling kernel is used by a CAD system, as this characteristic often has implications for the format in which the native model is stored, and hence, can be viewed. This information is given in the "Kernel" item for each product. A proprietary kernel typically writes a proprietary CAD model file format. Each system has one or more file formats—designated in the "File extension" item for each product. It should be noted that while most CAD systems can export model representations in other formats, the native format file extensions are listed in this document. Other file formats are given in subsequent sections.

- AutoCAD Inventor (Autodesk) http://www.autodesk.com/
  System type: CAD
  Brief description: A suite of components that do 2D and 3D design for the manufacturing industry. The suite includes Autodesk® Mechanical Desktop® for 2D design and Autodesk Inventor™ for 3D design.
  Kernel: proprietary
  File extension: .ipt, .iam, .idw, .dwf

- AutoCAD Mechanical (Autodesk) http://www.autodesk.com/
  System type: CAD
  Brief description: The AutoCAD solution for 2D mechanical design and engineering.
  Kernel: proprietary
  File extension: .dwg

- CADDS 5 (PTC) http://www.ptc.com/products/cadds/index.htm
  System type: CAD/CAM
  Brief description: CADDS 5 is a CAD/CAM suite that is based on a hybrid, concurrent engineering architecture, allowing large groups of engineers to simultaneously design, validate and machine the same product assembly.
  Kernel: PTC hybrid kernel (proprietary)
  File extension: (file extension not available—commonly referred to as 'CADDS 5' files)

- CATIA (Dassault Systemes) http://www.catia.com/
  System type: CAD/CAM/CAE
  Brief description: CATIA is a family of CAD/CAM/CAE software solutions for product life-cycle management developed by Dassault Systemes and marketed, distributed and supported by IBM. There are many compatible modules in the CATIA family to

meet various computer-aided design, manufacturing and engineering goals including data management for digital product definition and simulation.
Kernel: proprietary
File extension: model, export

- ICEM DDN (PTC) http://www.ptc.com/products/cadds/index.htm
  System type: CAD/CAM
  Brief description: ICEM DDN is a 3D CAD/CAM system for a large range of applications, from 2D design and drafting to complex surface and solid modeling. DDN stands for Design Drafting Numerical control.
  Kernel: proprietary, based on ACIS
  File extension: (file extension not available—commonly referred to as 'ICEM DDN' files)

- I-DEAS (EDS) http://www.eds.com/products/plm/ideas/
  System type: CAD/CAM/CAE
  Main use: Applications using master product models to enhance innovation
  Brief description: I-DEAS, part of the Unigraphics suite, is a CAD/CAM/CAE solution. This product purports to support the facilities to develop digital master product models, with the assumption that this concept will better support understanding products from a "manufacturability" standpoint during the early design stage.
  Kernel: proprietary
  File extension: .mca, .idi, .idz

- IronCAD (Ironcad) http://www.ironcad.com/
  System type: CAD
  Brief description: Solid modeling software for mechanical designers and engineers. IronCAD provides an alternative to history-based, parametric systems, utilizing a drag and drop 3D environment with Direct Face Modeling that provides design flexibility with the ability to generate fully associative manufacturing drawings.
  Kernel: proprietary
  File extension: .ics, .icd, .icc

- MicroStation (Bentley) http://www2.bentley.com/products/default.cfm
  System type: CAD
  Brief description: MicroStation is the foundation of Bentley's CAD solutions. Discipline-specific applications are available for civil engineering, transportation, process plants, discrete manufacturing facilities, utilities, and telecommunication networks.
  Kernel: proprietary
  File extension: .dgn, .cel, .svf

- Pro-Engineer (PTC) http://www.ptc.com/
  System type: CAD/CAM
  Brief description: A 3D product development solution, spanning the entire product development process, from creative concept through detailed product definition to serviceability.
  Kernel: Pro-Engineer (proprietary)
  File extension: .prt, .asm, .frm, .drw

- Solid Edge (EDS) http://www.solid-edge.com/
  System type: CAD
  Brief description: Solid Edge is a 3D CAD system for mechanical design. Associated
    tools are available for the machinery design and sheet metal industries.
  Kernel: Parasolid[7]
  File extension: .dft, .par, .asm

- SolidWorks (subsidiary of Dassault Systemes) http://www.solidworks.com/
  System type: CAD/CAE
  Brief description: SolidWorks offers solid modeling and 2D drawing capabilities, as well
    as Web publishing, animation tools, and photorealistic image generation.
  Kernel: Parasolid[8]
  File extension: .sldprt, .sldasm

- Unigraphics (EDS) http://www.eds.com/
  System type: CAD/CAM/CAE
  Brief description: Unigraphics is used by manufacturers to perform conceptual, industrial
    and detailed mechanical design along with engineering simulation and digital
    manufacturing.
  Kernel: Parasolid[7]
  File extension: .prt

4.2 Geometric Modeling Kernel Formats

A geometric modeling kernel lies at the heart of every commercially available 3D modeling application. A kernel is the library of core mathematical functions that the CAD system uses to define and store 3D shapes in response to users' commands. The kernel processes the commands, stores the results, and submits the output for display. There are basically three types of licensing arrangements for geometric modeling kernels: licensed, proprietary, and open source. Licensed geometric modeling kernels are developed and maintained by one company and then licensed to other companies for use in their CAD applications. Proprietary geometric modeling kernels are developed and maintained by a CAD application developer for use solely within its application. Open source geometric modeling kernels are similar to licensed kernels. They are developed and maintained by one company and then licensed to other companies for use in CAD applications.

- ACIS (Spatial, a subsidiary of Dassault Systemes)
  http://www.spatial.com/products/3D/modeling/ACIS.html?LV3=Y
  System type: Licensed geometric-modeling kernel
  Brief description: ACIS®, is the de facto 3D solid modeling foundation for a variety of
    3D products[7], including CAD/CAM/CAE, animation, and shipbuilding. ACIS was
    the initial offering in 3D-modeling component technology. Newer versions of ACIS
    bundle components to give software developers various types of functionality from
    which to build applications, such as blending, local operations, precise hidden line,

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[7] Information on Parasolid is available at http://www.wave-report.com/1999%20Wave%20issues
/wave9070.html

shelling, space warping, advanced surfacing, cellular topology, and a visualization manager.

File extension: .sat, .sab

- Open CASCADE (Matra Datavision) http://www.opencascade.com/

  System type: Open source geometric-modeling kernel

  Brief description: Open CASCADE is a set of reusable C++ libraries and development tools for the development of 3D modeling applications. The majority of Open Cascade is available as open source. This means that the source code is publicly available for software developers to use and modify. Some specialty components are available for purchase.

  File extension: .brep

- Parasolid (EDS) http://www.eds.com/products/plm/parasolid/

  System type: Licensed geometric-modeling kernel

  Brief description: Originally designed for high-end, mechanical CAD applications, Parasolid is now used in a wide diversity of mid-range systems. Parasolid is currently the fastest growing modeler available for license by MCAD developers, according to its developer, UGS (now EDS). Parasolid provides technology for solid modeling, generalized cellular modeling, and integrated free-form surface and sheet modeling.

  File extension: .x_t, .x_b

- SMLib (Solid Modeling Solutions) http://www.smlib.com/

  System type: Open source geometric-modeling kernel

  Brief description: SMLib is a set of Non-Uniform Rational B-Splines (NURBS) -based geometry and topology libraries that are used by more than 200 companies and universities. With integrated, nonmanifold-topology capability, SMLib includes a set of NURBS curve and surface modeling functions as well as code for object-to-object distance measurements and ray firing.

  File extension: .iwp, .iwb, .pbp

- Thinkdesign (think3, Inc.) www.think3.com

  System type: Proprietary geometric-modeling kernel

  Brief description: A shape-based, single-environment kernel. The architecture gives designers parametric solids, advanced surfacing, wire frame, and 2D drafting in a single CAD system. The nonmanifold topology of the thinkdesign kernel provides the ability to mix surfaces and solids, import and use imperfect 3D geometry, integrate 2D drawings into the 3D database; it also provides diagnostic information in the event a solid modeling operation cannot be completed. The kernel can also assign variable tolerances to different geometric entities.

  File extension: .e3, .e2

- VX Overdrive (Varimetrix Corp.) www.varimetrix.com

  System type: Proprietary geometric-modeling kernel format

  Brief description: VX Overdrive is an engine that provides 3D, hybrid-modeling capabilities and enterprise-level tools. VX Overdrive is a hybrid system that combines features of solid and free-form surface modeling. The system supports functions such as concurrent engineering, object versioning, history control, filleting/blending, undo/redo, and in-context modeling of assemblies.

  File extension: .vx

4.3 Exchange Specifications for CAD Data

Exchange specifications are neutral (non-proprietary) specifications for shape and product data exchange. Relevant specifications include the following:

- IGES – American National Standards Institute (ANSI) Y14.26M
  System type: exchange specification
  Brief description: Initial Graphics Exchange Specification (IGES) is a specification enabling the transfer of two- and three-dimensional drawing data, in a fixed-file format, in an electronic form. Although IGES serves its purpose of exchanging CAD data between different CAD systems, limitations of the standard include lack of upward compatibility due to the fixed file format, and most importantly, the restriction of information exchange to shape-related data only, rather than covering complete product data. Implementation problems include inability to handle large file sizes and long processing times. Despite these limitations, IGES is supported by most CAD products and is widely used for CAD data exchange [Bertoline 02].
  File extension: .iges, .igs

- SET – Standard d'Echange et de Transfert
  System type: exchange specification
  Brief description: SET was designed to address the difficulties in using IGES. The initial drivers for the effort were the automotive and aerospace industries. SET version 1.1 was contributed toward the STEP standardization activity [Goldstein 98] (see below).
  File extension: .set

- STEP AP203
  System type: exchange specification
  Brief description: STEP (STandard for the Exchange of Product model data) is a set of standards for complete product data definition and exchange under the international standard ISO 10303. STEP specifications are realized as application protocols (APs). STEP AP203—Configuration Controlled Design—supports the transfer of 3D CAD models, specifically advanced boundary-representation (b-rep) solids, basic wireframe, assembly information, and configuration management data—such as product I.D., version, and description. STEP uses an ASCII-based file serialization format (STEP part 21) that is human readable. STEP AP203 is widely implemented. Almost all major CAD systems will accept this format [Jones 00].
  File extension: .stp, .step

- STEP AP214 – ISO 10303-214
  System type: exchange specification
  Brief description: STEP (STandard for the Exchange of Product model data) is a set of standards for complete product data definition and exchange under the international standard ISO 10303. STEP specifications are realized as application protocols (APs). STEP AP214—Core Data for Automotive Mechanical Design Processes—supports the transfer of geometry data as well as design features, tolerances, 2D drawings and the STEP product data management schema. AP203 and AP214 geometry are essentially identical.
  File extension: .stp, .step

- VDAFS – VDA Surface Data Interface format
  System type: exchange specification
  Brief description: VDAFS is used by the German Motor Manufacturers Association
    (VDA) to exchange 3D CAD model data. VDAFS was published as a German
    national standard in 1986. A number of automotive manufacturers and suppliers
    throughout Europe use the standard to exchange surface data used in the design of
    automotive tooling and components such as body parts, injection molded parts, seats,
    panels, and so on.
  File extension: .vda

4.4 Other File Formats Relative to the Exchange of Graphics Data

- BMP (Bit Map)
  System type: graphics file format
  Main use: Bit-mapped or raster graphics file format for the Windows environment.
  Brief description: The standard bit-mapped graphics format used in the Windows
    environment. Bit maps are representations of graphics images, consisting of rows and
    columns of dots, of a graphics image in computer memory. The value of each dot
    (whether it is filled in or not) is stored in one or more bits of data. For simple
    monochrome images, one bit is sufficient to represent each dot, but for colors and
    shades of gray, each dot requires more than one bit of data. The more bits used to
    represent a dot, the more colors and shades of gray that can be represented. Bit-
    mapped graphics are also referred to as "raster graphics."
  File extension: .bmp

- GIF (Graphics Interchange Format)
  System type: graphics file format
  Main use: scanned photos, World Wide Web graphics
  Brief description: a bit-mapped graphics file format used by the World Wide Web,
    CompuServe and many Bulletin Board Systems. GIF supports color and various
    resolutions. It also includes data compression, making it especially effective for
    scanned photos.
  File extension: .gif

- HPGL (Hewlett-Packard Graphics Language)
  System type: page description language
  Main use: printers and plotters
  Brief description: a set of commands for controlling plotters and printers. HPGL is part
    of Hewlett-Packard's PCL Level 5 page description language. PCL stands for Printer
    Control Language, the page description language (PDL) developed by Hewlett
    Packard and used in many of their laser and ink-jet printers.
  File extension: .hgl, .hpg, .plt, .prn

- JPEG (Joint Photographic Experts Group)
  System type: graphics file format
  Main use: color photos
  Brief description: JPEG is a lossy compression[8] technique and file format for color images. Although the technique can reduce files sizes to about 5% of their normal size, some detail is lost in the compression.
  File extension: .jpg, .jpeg

- STL (stereolithography)
  System type: file format
  Main use: 3D printers and rapid prototyping machines
  Brief description: The STL file format is commonly used on most 3D printers and rapid prototyping machines. It can be exported from many CAD packages.
  File extension: .stl

- TIFF (Tagged Image File Format)
  System type: graphics file format
  Main use: high-resolution graphics
  Brief description: TIFF is one of the most widely supported file formats for storing bit-mapped images. TIFF graphics can be any resolution, and they can be black and white, gray-scaled, or color.
  File extension: .tif, .tiff

- VRML (Virtual Reality Modeling Language) http://www.w3.org/MarkUp/VRML/
  System type: modeling language
  Main use: create "virtual worlds" accessible via the World Wide Web
  Brief description: VRML allows creation of "virtual worlds" networked via the Internet and hyperlinked with the World Wide Web. Aspects of virtual world display, interaction and internetworking can be specified using VRML without being dependent on special gear like head-mounted devices (HMD). It is the intention of its designers to develop VRML as the standard language for interactive simulation within the World Wide Web.
  File extension: .wrl

4.5 Visualization Middleware

Computer graphics tool sets have been developed for assisting computer programmers in displaying images in end-user applications. This type of tool set is categorized as "middleware" in the computer industry. Some of these tool sets have been used for developing applications for displaying CAD models. Examples of these technologies include

- EON Studio (EON Reality) http://www.eonreality.com/
  Brief description: EON Studio is a graphical-user interface (GUI) based tool for developing real-time 3D multimedia applications focused on E-commerce/marketing, E-learning/training and Architecture. The development process includes importing different 3D objects, usually originating from different modeling tools such as 3D Studio or Lightscape, or from different CAD systems such as ArchiCAD, ProE, or

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[8] Lossy compression is a data compression technique in which some amount of data is lost. This type of compression technology attempts to eliminate redundant or unnecessary information.

CATIA. Once imported, behaviors can be associated with the models through EON's graphical programming interface, scripting or compiled C++ code. Simulations can also be integrated in other tools, such as Powerpoint, Word, Macromedia Authorware, Director, Shockwave, and Visual Basic.

- Immersive Design's IPA (Interactive Product Animator) http://www.immdesign.com/
  Brief description: IPA is the communication tool for Pro/ENGINEER, Unigraphics, I-DEAS, SolidWorks, and Solid Edge, that provides product information across an enterprise in the form of highly visual full motion animations. The animations are compatible with Microsoft applications, and can be embedded in documents, presentations, and Hyper-Text Mark-up Language (HTML) pages.

- Autodesk VIZ (Autodesk) http://usa.autodesk.com/adsk/
  Brief description: With its technological roots in 3ds max,™[9] Autodesk VIZ (formerly 3D Studio VIZ) provides tools for digital creation and output. Combined with the latest global illumination rendering capabilities, these tools provide a rendering for rich images that help predict what a design will look like under various lighting conditions.

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[9] More information on 3ds max is available at http://www.3dmax.com/

5 Commercial Product Information

The following table provides overview information for available, circa the date of this research,[10] COTS viewing technologies supporting multiple formats or formats that can be exported from a variety of CAD systems such as ACIS or stereolithography files. Information for each product includes product name, company name, price, computer platform support, supported files, contact information, URL for accessing additional information, and additional comments that typically describe the main product features. Any commercial product identified in this document is for the purpose of describing a software environment. This identification does not imply *any* recommendation or endorsement by the National Institute of Science and Technology, the Software Institute, Carnegie Mellon University or the Transition Insertion Demonstration Evaluation (TIDE) Program.

Editor's note—The use of non-native viewer technology carries some risk that the view as rendered will vary from the native products rendering of the model. Relying upon these views must be done with appropriate situational awareness. That is, will the sourcing or using organization accept the consequences of non-native viewer misinterpretation of a model?

The ever-evolving state of the native packages also implies that the non-native viewers must lag this evolution, creating vulnerability that the native packages evolution will make obsolete the non-native packages' capabilities. Process considerations should be made for this situation; for example, if the reviewers' tool (CADviewer) differs from the designer's tool, perhaps a validation of the CADviewer's rendering should be done by the design team before it is released to the reviewer community.

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[10] It should be noted that information in this section is current circa March 2002. The reader should be aware that this information is time sensitive and that changes in product offerings and pricing occurs over time.

Table 1: Commercial Product Information

Product Name Company Name Web site	Price Info (1 seat)	Platform support	Supported file formats	Contact information	Comments
3D-Tool Ingo Wulf http://www.3d-tool.de/	76.69 EUR	Windows 95/98/NT/2 000	Pro/ENGINEER SLP or STL	Email: i.Wulf@3D-Tool.de	Provides edit (change colors), move, rotate, scale, and print capabilities.
3Dview Actify http://www.actify.com/	<$500 for base system; additional components available for selected CAD model formats	Windows 95/98/NT/2 000	Base system: IGES, VDA-FS, AutoCAD/Mechanical Desktop files (.DWG, .DXF, .DWF, and .SAT), STL, HPGL, ISO G-Code, VRML, RAW, 3DStudio, and Actify's .3D. Optional importers: http://www.actify.com/v 2/products/3dview/form ats.htm including: CATIA, PRO/E, SolidWorks, UG, Solid Edge, SDRC, AutoDesk Inventor, Parasolid, STEP	Tel: +1-415-421-1840 Email: Sales@actify.com	Provides viewing, measurement, multimedia mark-up, cross-sectioning, dimensioning, mass properties, and export of images for documents. SpinFire is the free Web plug-in from Actify for *3DView* visualizations.
ACIS® Open Viewer Spatial http://www.spatial.com/produc ts/visualization/Components/vi ewer.htm?LV3=Y	free	Windows	.sat (ACIS), Microsoft® Office applications	Tel: +1-303-544-2900 or 1-800-767-5710 (U.S.A. only) Email: Info@spatial.com	A stand-alone viewer.

Product Name Company Name Web site	Price Info (1 seat)	Platform support	Supported file formats	Contact information	Comments
AutoVue Cimmetry Systems, Inc. http://www.cimmetry.com/cim web.nsf	$395, w/optional mark-up capability $595.	DOS, Windows 3.1, for Workgroups, 95, 98 NT, 2000, JAVA 2000 and UNIX	See downloads/product selection guide: http://www.cimmetry.co m/cimweb.nsf	Tel: 1-800-361-1904 Email: sales@cimmetry .com	Supports 2D CAD formats; available in thick and thin clients; multiple languages; regular and professional versions provide viewing capability but differ in mark-up capabilities.
AutoVue SolidModel Cimmetry Systems, Inc. http://www.cimmetry.com/cim web.nsf	$995, w/optional mark-up capability: $1495.	Windows 3.1, 95, 98, NT, 2000, XP	See downloads/product selection guide: http://www.cimmetry.co m/cimweb.nsf	Tel: 1-800-361-1904 Email: sales@cimmetry .com	Supports 3D CAD formats; regular and professional versions provide viewing but differ in mark-up capabilities.
CADViewer Tailor Made Software, Ltd. http://www.cadviewer.com	>$1k	For use with Web servers, e.g., Internet Explorer and Netscape	DWF, SVF; Enterprise version supports: DWG, DXF, HPGL, PostScript and PDF	Tel: +1-206-910-5674 Email: sales@tailormad e.com	Java-based, 4 license arrangements available.
CtrlView Alexandre Matveev http://www.ctrlview.com/inde x.html	$30	Windows 95/98/Me /NT/2000	http://www.ctrlview.com /input.html including TIFF, HP-GL, HP-GL/2, Autodesk 3D Studio (3DS), Stereolithography (STL), VRML (WRL)	Email: amatveev@Ctrl View.com	Provides viewing and converter capabilities.

Product Name Company Name Web site	Price Info (1 seat)	Platform support	Supported file formats	Contact information	Comments
DesignGateway SofTech http://www.designgateway.net/	1 CAD module: ~$800	Windows NT/2000/98	Reads solid model files from CATIA, SolidWorks, Pro/ENGINEER, SDRC I-DEAS, Unigraphics, and thinkdesign	Tel: 800-800-3702 or +1-978-640-6222 Email: marketing@softech.com	Integration with CADRA (2D drafting) and MS Office products. Provides viewing and document management capabilities.
DIVISION Product View PTC http://www.ptc.com/products/windchill/	Base: $2000, Realizer option: $4995. + annual maint.	Unix, Windows	DWG, IGES, PRO/E, CADDS, CATIA, I-DEAS, UG, Solidworks, STL, VRML, etc. List: http://www.ptc.com/products/division/productview_2d3d_formats.pdf	Tel: 888-782-3776; List of contacts: http://www.ptc.com/company/contacts/index.htm	Base product capabilities: view, mark-up, calculate mass properties, create rendered images, rotate, fly-through, and create sections through an assembly. Realizer option capabilities: clash detection analysis, create animations and export MPEG movies.
DraftView for CADDS Draftware Developers, Inc. http://www.draftware.com/dvhome.htm	$425-$625	MS-Windows, Solaris and HP-UX	Native CADDS 4X and CADDS 5, CGM, DWG, DXF, GIF, HPGL, JPG and TIFF	Tel: +1-812-427-2572 Email: Info@draftware.com	Provides view, print, and mark-up capabilities; views model directly from the CAD database.
DraftView for Personal Designer Draftware Developers, Inc. http://www.draftware.com/dvhome.htm	$425-$625	Microsoft Windows, DOS and SPARC	Native Personal Designer® and microDRAFT®, CGM, DWG, DXF, GIF, HPGL, JPG and TIFF	Tel: +1-812-427-2572 Email: Info@draftware.com	Provides view, print, and mark-up capabilities; views model directly from the CAD database.

Product Name Company Name Web site	Price Info (1 seat)	Platform support	Supported file formats	Contact information	Comments
FastLook Plus Kamel Software http://www.kamelsoftware.com/fastlook/overview.htm	$345	All Windows platforms	>200 formats, including: AutoCAD, Inventor, SolidWorks, MicroStation, Cadkey, ME 10/30, DXF, HPGL, TIFF, Cals G4. http://www.kamelsoftware.com/fastlook/list.htm	Tel: +1-407-672-0202 Email: Sales@kamelsoft.com	Provides viewing, mark-up, and plotting capabilities. Provides network administration for access control and has open APIs available.
ForReview™ Allegria Software http://www.allegria.com/products/forreview.htm	$299 + (annual maint. 18%)	Windows 95, 98, NT, Unix	>150 formats, including: AutoCAD, HPGL, MicroStation, IGES, SolidEdge, Unigraphics. http://www.allegria.com/products/forreview-file-format-support.htm	Tel: +1-714-974-2500 Email: jgray@web4inc.com	Provides view, mark-up, compare, and print capabilities.
Imagenation® Spicer Corp. http://www.spicer.com/Product_web/ImageaX/ImageaX-Overview.htm	View module: $395; View + mark-up module: $695.	Win9x/NT 4.0/2000/ME	>150 formats, including CAD http://www.spicer.com/Product_web/imagenation/imagenation_view.htm	Tel: +1-330-758-1112 Email: info@spicer.com	Thick client. View module provides view capability. Optional module provides mark-up, scan, and edit capabilities.
InViso Informative Graphics http://www.infograph.com/products/dwgviewer/	$49	Windows NT 4.0 or Windows 95/98	DWG/DXF/DWF, SolidEdge, SolidWorks, ME10, HPGL, CGM, DGN, TIFF, and CALS http://www.infograph.com/products/inViso/inVisoReadme.htm	Tel: +1-602-971-6061 Email: info@infograph.com	Provides view and print capabilities. Myriad is the full function version.
Myriad	$195	Windows	>150 formats, including:	Tel: 800-398-	Provides view, print/plot, publish,

Product Name Company Name Web site	Price Info (1 seat)	Platform support	Supported file formats	Contact information	Comments
Informative Graphics http://www.infograph.com/products/productsmyriad.htm	(PDF, CATIA, PRO/E extra)	NT, 95, 98, 2000	Pro/E, CATIA, Solid Edge, Solid Works. http://www.infograph.com/products/Myriad/MyriadFormats.htm	7005 Email: Sales@infograph.com	mark-up, cross-sections, measurement, and comparison capabilities.
Normica View & V2000 IT Base http://www.it-base.com/it-base_e/index.htm	$195 (View) $395 (V2000)	Windows 98/XP and Windows NT/2000/XP	HP-GL/2	Email: Info_us@it-base.com	View product: View and print drawings. V2000 product: View, edit, print drawings.
OneView Professional CAD Centric http://www.cadcentric.com/	$525	Windows 95/98/NT	SDRC (.asc, .dwg, .mdf, .idi), Solid Edge (.prt, .asm), STL, TIFF, HPGL	Tel: +1-513-554-6580 Email: info@cadcentric.com	Provides view, mark-up, and 3D PMI support capabilities. Integration options available.
SolidView Solid Concepts, Inc. http://www.solidview.com/	Lite – free SolidView - $99	Windows 95, 98, ME, NT, 2000 and XP, without hardware acceleration	http://www.solidview.com/compare.html#3dformats	Tel: +1-661-257-9300 Email: Webmaster@solidconcepts.com	Lite version is a reader for the proprietary exchange format (SFX). SolidView provides view and measurement capabilities.
SolidView/Pro Solid Concepts, Inc. http://www.solidview.com/	$495 (optional importers: $295-$495 each)	Windows 95, 98, ME, NT, 2000 and XP, without hardware acceleration	http://www.solidview.com/compare.html#3dformats	Tel: +1-661-257-9300 Email: Webmaster@solidconcepts.com	Provides view, publishing, translation, scale, rotate, mirror, measurement, cross-section, and access control capabilities.

Product Name Company Name Web site	Price Info (1 seat)	Platform support	Supported file formats	Contact information	Comments
STL-Viewer Floating Point Solutions http://www.fpsols.com/stl_viewer.html	free	Windows	Stereolithography (.stl)	Tel: +1-413-235-7988 Email: Info@fpsols.com	Provides view and print capabilities.
ST-Viewer STEP Tools, Inc. http://www.steptools.com/products/stviewer/	$290	Windows NT 4.0/2000 or Windows 98/95	Systems tested with ST-Viewer: ACIS, Alias Wavefront, AUTOCAD, CADKEY, CATIA, CoCreate, Microstation, Parasolid, Patran, Pro/ENGINEER, SDRC I-DEAS, SolidEdge, SolidWorks, IronCAD, UNIGRAPHICS	Tel: +1-518-687-2848 Email: info@steptools.com	Supports the following APs: AP 203, AP 209, AP 214, AP 224, AP 227, AP 210. Provides view and mark-up capabilities. Additionally, displays and relate product identification information, assembly structure information, and 3D geometry information.
Trix DrawingCenter 2000 Trix Systems http://www.trixsystems.com/dcenter.html	$139	Windows XP, 2000, NT 4.x, ME and 95/98	DWG, DXF, PLT (HPGL), C4, CALS, TIF, BMP, etc.	Tel: 800-326-4443 Email: info@trixsystems.com	Provides view, mark-up, measurement, and print capabilities.
ViewCafe Spicer Corp. http://www.spicer.com/Product_web/ImageaX/ImageaX-Overview.htm	10 concurrent seats + Web server component: $3995.	Win9x/NT 4.0/2000/ME/XP	>150 formats, including CAD http://www.spicer.com/Product_web/ViewCafe/java_supported file formats.htm	Tel: +1-330-758-1112 Email: info@spicer.com	Provides Web-based view and mark-up capabilities.
ViewCompanion	$45	Windows	HPGL and HPGL/2	Tel: 877-353-	Regular version provides view and

Product Name Company Name Web site	Price Info (1 seat)	Platform support	Supported file formats	Contact information	Comments
Software Companions http://www.softwarecompanions.com/viewcomp.html	(regular) $59 (Pro)			7297 E-mail: sales@softwarecompanions.com	print capabilities, as well as the ability to export other formats. Pro version provides an additional mark-up capability.
Vis View Standard EDS http://www.plmsolutions-eds.com/products/	$1030 1 floating seat; node-lock $500	Windows & Unix	VRML 1.0 and STL; optional support for I-DEAS, Pro/ENGINEER, CATIA, CADDS and Unigraphics; Separate neutral format translators for IGES, STEP, AutoCAD DXF.	Tel: 800-498-5351	Provides 2D view, measurement, mark-up, comparison, and 3D view capabilities. Additional options available.
Vis View Professional EDS http://www.plmsolutions-eds.com/products/	$3000 1 floating seat; node-lock $1750	Windows & Unix	VRML 1.0 and STL; optional support for I-DEAS, Pro/ENGINEER, CATIA, CADDS and Unigraphics; Separate neutral format translators for IGES, STEP, AutoCAD DXF.	Tel: 800-498-5351 List of contacts: http://www.eds.com/products/plm/contact/	Includes Vis View Standard capabilities and provides 3D advanced viewing options, 3D measurement and comparison capabilities. Additional options available.
WiseView Samsung SDS http://www.samsungsdsa.com (Pro & Enterprise versions – depends on options purchased)	Desktop $200-1300 Client/server – same $$ range	Windows 98, NT, 2000 (desktop & thin client w/server)	CATIA, STL, DGN, IGES, Solidworks, Unigraphics, Pro-E, many office formats	Email: wiseview_sales@usa.samsung.com	Provides view, mark-up, measurement, comparison, and conversion capabilities.
WorkView3D	399 CHF	Windows95/	VRML-2.0,	Tel:	(Switzerland)

Product Name Company Name Web site	Price Info (1 seat)	Platform support	Supported file formats	Contact information	Comments
DeltaConcept http://www.deltaconcept.ch	(PC) 399 CHF (linux) 499 CHF (Unix Motif)	98/NT, Unix Motif	3D Studio, STL, IGES, SAT.	+4122/827.69.9 0 Email: graphic@DeltaC concept.ch	Provides a view capability.

6 Conclusion

Visualization solutions offer the possibility of expanding engineering data review and collaboration to the extended enterprise. These tools allow product developers to view 3D models from different sites or from throughout an organization when multiple CAD systems are used.

Currently, there are many existing and evolving technologies that meet niche market needs. This situation is very fluid as new firms, new commercial arrangements, and new technologies and capabilities continue to emerge. Users of these technologies, after assessing their current and future needs, must seek solutions in the changing marketplace knowing that comparative product evaluations are unlikely to be valid for more than a year. To facilitate that evaluation, this paper provides guidelines that can be used by the community of smaller manufacturers facing such an evaluation task.

References

The URLs below are accurate as of September 2003.

[Bertoline 02]   Bertoline, G. & Wiebe, E. *Fundamentals of Graphics Communications*, 3rd Edition. New York, NY: McGraw Hill, 2002.

[Goldstein 98]   Goldstein, B.; Kemmerer, S.; & Parks, C. "A Brief History of Early Product Data Exchange Standards," NISTIR 6221. Gaithersburg, MD: National Institute of Standards and Technologies, 1998.

[Jones 00]   Jones, B. "STEP comes of age," *CAD Systems Magazine* (Jan. 2000) <http://www.cadsystems.com/archive/0001f03.html> (2000).

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13. ABSTRACT (MAXIMUM 200 WORDS)

This report provides information about technologies for viewing computer-aided design (CAD) models. CAD model viewers are tools that allow engineers and other users to view CAD models from distributed locations, often using lightweight viewing applications or standard Web browsers. The report describes factors to consider when choosing a viewing technology, as well as popular CAD model file formats that viewing technologies can import. Also provided is a sampling of commercial off-the-shelf (COTS) products currently available for viewing CAD models; descriptive information for each product, such as basic product functionality, purchase price, computer platform support, file format support; and a related World Wide Web Universal Resource Locator.

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